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BETTER ROADS

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1. INTRODUCTION

In this pamphlet we are going to talk about roads: not the big national highways or even the state roads, but the humble roads of the countryside.

Why are village roads so important? There are several reasons. For one thing, they open up the rural areas for economic development. Village products are more easily marketed, and the return flow of trade brings in goods from the towns and medical, educational and other welfare services which help to raise living standards. Not only that. New ideas are spread as the people of one village meet people from other villages and the towns. Cultural and social activities grow, and people take an increased interest in life. So you see how important our village roads are in the spreading of cultural ideas and in economic development!

Unfortunately, in the past we have paid very little attention to our village roads. Even now, neighbouring villages are connected only by foot-paths, and in the better developed areas by cart-tracks. Undoubtedly these tracks served the purpose while people were content to move from place to place by bullock-cart. Now, however, we have to provide better roads, many of which must be suitable for motor traffic—roads moreover which will survive the fury of the monsoon, so that the villages may not be cut off from the towns and from each other for as long as three months in the year, as at present.

The task is by no means going to be an easy one. It is not just a matter of building a few roads here and there. Just think: there are over 5½ lakhs of villages scattered throughout the length and breadth of this land. We have

to cater for them all. A staggering figure, isn't it ? And not all of them are situated in flat, dry areas where it is comparatively easy to build roads. Many lie in wild, mountainous country. Others are surrounded by thick jungle, others still by swamps.

It will be many years before we can hope to achieve our aim of having at least one good road leading to every village. For one thing, we do not at present have the money needed for a large road-building programme. The people themselves can, however, bring this date nearer by coming forward to help. Those in the Community Project and National Extension Service areas have already set a fine example. Let us follow them, remembering that every little bit of voluntary work done carries us further towards our goal.

2. ALIGNMENT AND SURVEY

It is surprising how many people think of road-building as a simple matter of laying strips of earth, reinforced by stones, and beating it down to form a level surface.

Or is it surprising ? After all, that is what the common man sees; it is, shall we say, the *visible* part of road-building.

There is, however, much more to it than that. You know that when a General plans his campaign, or a housewife her monthly budget, there are so many things to be taken into account. In the same way, in building a road we have to think of such problems as the best route to be followed, the type of surface to be provided and the need for efficient drainage. Hill roads, too, have their special problems. All these have to be considered before the actual manual work begins.

Taking these problems in the order in which they appear, the first thing we have to consider is the route

which is to be followed—in technical language, the alignment of the proposed road. This itself is a complicated task; there are several factors to be taken into account, some of them engineering, some economic.

The engineering factors include the gradient or slope of the ground, the nature of the soil, the rivers or *nallahs* to be crossed and the availability of material such as *moorum* or stones used in road construction. These points need to be explained. The slope of the ground is important because the villagers' chief means of travel is still the bullock-cart. The road must not be so built as to put undue strain on the animal. Moreover, as most village roads will for some time continue to be made of earth, gentler slopes will give them more protection from flowing rain-water.

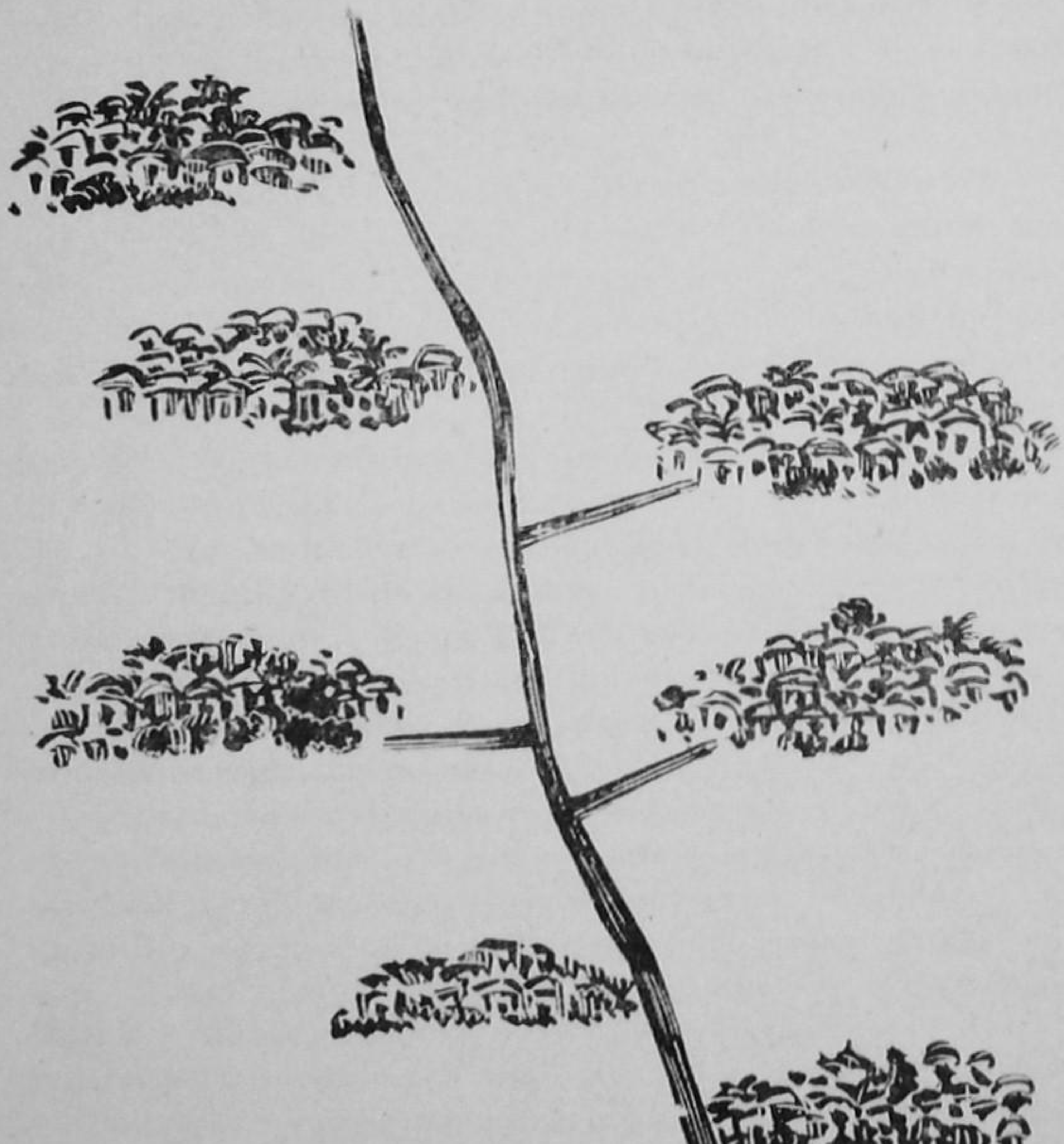
What of the soil ? One that is easily drained and does not shrink is ideal. In general, *moorum* soils are good, while those with a large clay content are unsuitable as they have a tendency to shrink. We must be careful to choose a type of soil which is both suitable for embankments and has good drainage properties.

Streams and ditches present one of the biggest problems in road-building. We must build bridges in positions where the banks are in no danger of crumbling through erosion and are generally not subject to flooding. Bridges are easily built over waterways which are less than 20 ft. wide. Such streams should, therefore, be bridged to keep the number of traffic obstacles to a minimum. For the bigger streams, however, it is sometimes sufficient to provide causeways. We can save on costs this way. But won't causeways be under water during the rainy season? That is so and, therefore, we can only have them on the less important roads. The important roads must have bridges so that they remain open in all weathers.

The fourth engineering factor is the availability of road materials. In selecting one of two alternative routes, preference has to be given—other things being equal—to the route nearest the local quarries. *Moorum*, coarse gravel

and sandy loam are all good materials for village roads. (It is especially desirable to provide a firm top for clay or sandy soils). Soft stone such as *kankar*, laterite or sandstone is, however, to be preferred if locally available.

Among the economic factors that influence the route a road is to take is the number of villages proposed to be served and the economic importance of the area. There is also the question of economy of length, for obviously we are not going to build six miles of road where five miles would serve the purpose.



There are three possible ways of making a road to serve a group of villages. One, which on paper is the simplest method, is to build from village to village in turn. A second is to lead off branch roads to the villages from a main highway. The third method is a combination of the first two and calls for a road passing through those villages which lie roughly in a straight line, with branch roads leading off to the others. The last method is usually followed.

An important point to remember is that the road must go round a village and not through it. Do you know why this is so? One reason is that a road inside a village generally has many blind corners, and there is always the danger of accidents. Another reason is that a road which has houses on either side cannot be broadened. We have to look ahead: the village road of today may be a main road tomorrow. We must leave room for expansion.

As a good road is an agent, as it were, of the economic development of an area, it is not difficult to see that it increases the value of the land along it. For this reason, land-holders are usually only too willing to donate pieces of land for a proposed road. The difficulty is that the donated land is usually in the form of strips along the boundaries of fields. Moreover, the land given by various people is unlikely to form one continuous line; or if it does, the line may wind so much as to make the building of the road a very costly business. So, right at the very beginning it is necessary to persuade the land-owners to give land which is more or less in a straight line. Remember, length saved is money saved!

Survey: We have now discussed the factors which govern the route a road should take. They include the slope of the ground, the soil, the presence of streams and ditches, the economic importance of the area, the number of villages, economy of length, and so on. Now, it is very rarely that a route will be found which will fit all the requirements. Usually, it is a question of which route meets more of the

important conditions than the other possible ones. To decide this, a careful survey has to be made.

The first step is to get hold of survey maps of the area in the largest scale available, and with the help of these plot possible routes. In addition to the factors already mentioned, the points where the routes cross existing roads, railways and canals have to be noted, and care taken to avoid cemeteries, temples, mosques, etc. The officer entrusted with the survey then walks along the various possible alignments in turn, and decides which is the most suitable.

The preliminary work does not end with choosing the alignment. There are also such questions as land width, formation width and the curves of the proposed road to be considered.

In deciding what width of land is needed for the road, we have to think of several things. Firstly, is the road to be an important one? Will it carry heavy traffic? If so, it must be wider than other roads in the area. Then there is the question of the height of the embankment. The higher the embankment, the more the land that will be required for the side slopes leading down to the level of the countryside. We have also to bear in mind the land required for stacking construction materials such as *moorum* and metal, as well as the borrow-pits needed to provide earth for maintenance. There must, moreover, be room for drains on either side of the road. Normally, the land width for village roads works out to between 40 and 60 ft. For district roads the width is generally between 40 and 80 ft. or 80 and 100 ft., depending on the importance of the road.

We must not forget to look to the future as well. The village road will not always be what it is at the moment, serving a limited purpose. As the area is developed, there will be more traffic and the road may have to be widened. Bearing this in mind, it is easy to see that we must control the construction of buildings on both sides of the road. No building should be allowed within 40 ft. on either side of

the centre line of a village road; there should also be an additional strip of 10 ft. on either side where temporary structures may be erected only on the understanding that they will be pulled down later, if necessary. These figures apply to village roads. For district roads we have, of course, to increase the limits by 20 ft. or more.

After the land width, our next problem is the formation width. This is the over-all width of the top of the embankment or, in a case where there is no embankment, the width between the side drains. The minimum formation width of a village road should be 18 ft., and that of a district road 24 ft. In most cases, however, it is best to have a width of 24 ft. for the village road as well. Within the formation width we have what is called the carriage-way. This is the specially prepared surface on which vehicles actually travel. The width of the carriage-way depends on the types of vehicles which will be using the road and the amount of traffic in both directions. As village roads are mainly used by bullock-carts, a 10 ft. carriage-way is ordinarily sufficient for traffic up to 200 tons per day, i.e., about 150 loaded vehicles. If the traffic is fairly heavy, and there is frequent crossing of vehicles, the carriage-way should, however, be at least 12 ft.

We now come to the third problem—curves. On roads used solely by bullock-carts, this raises no immediate difficulties. But, as has been pointed out, we must think ahead of the day when there will be motor traffic. Motor vehicles which take sharp curves at high speed are in danger of overturning or skidding off the road. We must, therefore, make every curve as gentle as possible.

3. EARTH ROADS

We have now decided what route the road will take. The preliminaries are over, and the time has come to get

down to the actual construction work. But there is one more thing. Is this going to be an ordinary village road or an important road connecting a group of villages and perhaps linking up with a main highway? If the road is going to be an important one, it will have to be provided with a water-bound macadam surface, such as we shall describe in the next chapter. If, however, it is to be a quiet village road, there is no point in spending a great deal of money on it just now. We shall make it an earth road. Later, perhaps, when the area develops and traffic increases, we shall convert it into a water-bound macadam road.

In an earth road, the first thing to be tackled is the embankment. We start by marking the central line along the chosen alignment. When this is done, the entire area of the proposed embankment is cleared of trees, scrub, roots and boulders, and the surface is roughly levelled. If the path lies through cuttings in hard rock, it may be necessary to remove obstacles by blasting.

In highly developed countries like the U.S.A., this work of preparing the ground is done by labour-saving machines like the bull-dozer, angle-dozer and grader. Each of these machines has a blade of hard steel 6 to 9 ft. wide, which is pushed into the ground by a powerful engine. In the bull-dozer the blade can only be moved up and down. In the angle-dozer it can also be turned within certain angles, and the grader is an improvement even on that. Machines are of great help in countries where labour is very costly. In India, however, it is labour which is cheap and machines costly. We cannot afford machines at present, so instead we have swarms of people working away with their small tools and baskets on our national highways and village roads alike.

Returning to our building. After the area is cleared, pegs are driven into the ground along the edges of the formation at intervals of 100 ft. on straight sections and 20 ft. on curves. The pegs on either side are then connected by thin ropes, and the ground is cut along the lines thus

formed. This process, which marks the limits of the embankment, is called "dagbelling."

The next step is to form the profile of the embankment. How we do it is this. Thin pieces of wood or bamboo poles are driven into the ground at intervals along the ends of

PROFILE OF THE EMBANKMENT

the formation. We know how high the embankment is going to be. From a point a little above that height (to allow for the earthwork to settle) on each pole we tie a string to a corresponding peg at the foot of the embankment. The slope of the string marks the profile or outline of the embankment as it will finally appear. In the case of cuttings, care has to be taken to leave room for drains on either side of the formation. In fact, in such cases it is best to cut the central road portion first, leaving the slopes to be dealt with later.

If the road passes through flooded fields, the top of the formation must be a foot above the water level in the fields. Otherwise, for village roads a one-foot embankment is usually enough, and where the alignment is along a watershed even this height is not necessary. Building an embankment costs money, and the higher the embankment the greater the cost. We must build only to the minimum height needed for safety during floods.

The side slopes of the embankment should, if possible, be gradual and not steep. Gradual slopes are good because they allow safe and easy drainage and are not cut up by rain-water. In rock cuttings, fairly steep slopes may be permitted, otherwise it is necessary to protect steep embankments from erosion by sowing coarse grass or by planting creepers that will hold the earth together.

Where do we get the earth for the embankment? Obviously it will not be economical to bring it from far. So what we do is to dig borrow-pits within the land width itself. These borrow-pits should be as far as possible from the foot of the embankment, and should be of the same size. If the work is done on payment, a narrow diagonal strip—called a "witness"—is left across each pit for the purpose of measuring the amount of earth taken out. Near every village it is a good thing to connect all the pits on each side of the embankment by a drain in order to prevent water collecting in them and becoming a breeding-ground for mosquitoes.

The soil used for the embankment has to be free of roots, vegetable matter etc. Clods should be broken up. Sand can be used, but not alone, as it is not stable; it must be confined within side-bonds of loam or clay about 2 ft. thick. It is important to remember that loose earth gradually settles down, and the embankment will appear to shrink after it has been built. We must make allowance for this in building up to a fixed height. An allowance of one inch for every foot in height is generally enough. Clay soils, however, shrink more than sandy soils and require a larger allowance.

We can, as a matter of fact, keep shrinkage to a minimum and ensure a strong embankment by building in a sensible way. The best plan is to deposit the earth in layers not more than 9 ins. thick, wetting the soil after each layer and rolling. The water must be just enough to bind the earth well—no more, no less. But how do we know when the amount of water is just right? A little experiment will show. We take a handful of soil and try to roll it into a ball with the help

of water. The least amount of water required to form a solid ball is what we want. When we have done this we have found (roughly) what the experts call the Optimum Moisture Content of the soil.

This is all very well, you will say, but how are we to know what is the Optimum Moisture Content of the tons of soil in the embankment? Surely we are not going to test all of it, handful by handful? That of course would be quite impossible. There is, however, a much easier way. As a result of our experiment we have a ball of soil containing just the right amount of water. We notice that this soil has a certain colour and consistency. So what we do is to continue watering till the earth all along the embankment is exactly the same colour and consistency. We will then have the strongest possible embankment.

Having laid down the earthwork, the next thing is to check the levels between the sets of profiles in order to ensure smooth gradients. These levels are checked with the help of an instrument called the "boning rod." This is a wooden board with a cross staff fixed at right angles at the top. Two of these rods are held at levels already known and the third at a point the level of which has to be checked. The last rod is raised or lowered till the cross staff is in line with the other two. In this position the third point is known to be on the same gradient (slope) as the other two, and the earthwork can be levelled up accordingly.

When first built, all embankments are uneven, and much levelling work has to be done. The side slopes, too, must be protected from erosion by the planting of grass or deep-rooted creepers. High embankments up against a stream have to be protected by "revetments", which are layers of stone about a foot thick packed on the slopes of the portion threatened. In the absence of a revetment, a thick layer of turf is the next best protection. The grass should be sown just before the monsoon, during which it grows fast.

After the embankment is complete, it is not desirable to go ahead at once with the job of metalling or surfacing,

if this is intended. The soil takes time to settle, and it is good to let the embankment lie exposed to the weather for a full monsoon. A slight slope towards the centre will enable the rain-water to soak in and will help the earth to settle. Later, of course, the surface will have to be dressed up so that the slope is the other way, from the centre to the sides. This is known as giving a "camber" to the roadway, and its aim is to prevent water collecting on the road and becoming a hindrance to traffic.

Earth roads, no matter how well they have been laid, wear away rather quickly under the combined attack of the weather and traffic. It is, therefore, necessary that we should try to make them as strong as possible. In recent years, scientists have been making a close study of soils, and have suggested methods of strengthening them when they are weak. There are three methods of soil stabilisation, as we call it. One is by adding cement, the second by adding bitumen and the third by mixing the clay of the road with sand or the sand of the road with clay, as the case may be. The first two methods are costly, and, therefore, are not common in India. In any case, we cannot afford to use them on our earth roads. This leaves only the third method. It seems simple enough, but there is one problem: in what proportions ought the sand and clay to be mixed? The experts tell us this, for experiments in their laboratories have shown just how much of each should be used to produce the strongest possible surface.

In our rural areas, however, and even in our Community Projects we do not have laboratories to help us find out the exact proportions of clay and sand needed. So we have to follow a rough-and-ready method. What we do is this: we know that the proportion of of sand in the mixture should be between 50 and 65 per cent. Having mixed the two soils when they are in a dry, powdered state, we take a wide-mouthed bottle or jam jar and pack it tightly with the mixture to a depth of about half the jar. Water is then added and the jar shaken vigorously. In about 5 minutes the sand settles to the bottom;

it can easily be made out by its colour. By comparing the height of the sand layer in the jar to the height of the entire mixture, the proportion of sand is known. Sometimes there may be too much sand; at other times too little. We must carry on changing the mixture until we get the right proportions.

Mixing, however, is not enough. The mixture has to be compacted—in other words, pressed firmly together—in order to form a hard-wearing surface. Experts tell us that the weight of the compacted mixture should be 120 to 130 lb. per cubic foot. This sounds very technical and difficult, but it is really not so. We take a box which on the inside is 1 ft. in length, 1 ft. in width and 1 ft. in depth. Such a box will hold 1 cubic foot of material. We then pack the box tightly with the soil mixture until it holds 120 to 130 lb. At this stage the compaction is just right.

Monsoon rain is an enemy of the earth road, which can be quickly ruined if care is not taken to provide good drainage. We have already talked about the practice of giving a camber or curve to the road surface to drain off rain-water. This camber must, however, be carefully prepared. If it is too steep, no bullock-cart will want to travel on the side of the road. All the traffic will be along the middle, and a rut will in time form on each side of the central line. Generally, in an earth road there should be a fall to the side of 1 inch in the level for every 24 ins. of roadway—a camber of 1 in 24, as the experts say. For a water-bound macadam surface (which we shall learn about in the next chapter) the slope usually ranges from 1 in 48 in areas of light rain to a steeper 1 in 36 in areas of heavy rain.

Drainage: Sometimes, in these areas of heavy rainfall, springs may rise from the ground and weaken the foundations of a road embankment. What should we do then? We can lay underground drains to take the water away from the road. The easiest way of making an underground drain is to dig a trench about 2 ft. wide, sloping downwards from the spring to one of the side drains. The trench is filled with boulders, loosely packed to allow the water to pass through.

Broken stone or *moorum* can be spread on top to form a level surface.

The side drains which we have just mentioned are very important. Not only do they carry away water which falls on the road and which seeps through springs in the road bed, but they also keep out water which flows towards the embankment from the surrounding land. Generally in the countryside drains should be 1 ft. deep and about 1½ ft. wide. They must be cleaned regularly, else they will soon be choked with silt and leaves and become useless.

If a road is cut along the slope of a hill, even the side drains cannot fully protect it from water which comes rushing down the hillside. So a second line of defence has to be built higher up the slope to catch the water and lead it off to a natural stream or a culvert. This type of drain, which is called a "catch-water drain," is usually about 3 ft. deep and 3 ft. or more wide. In places where the soil is soft, it is a good plan to line the catch-water drain with any hard material found in the area.

If an earth road is to give good service, it must be well looked after. Ruts and pot-holes must be filled in as soon as they appear. It is not really difficult to preserve the smooth surface and camber of the road. A drag does this job very well. It is made by splitting a log about 8 ft. long and 10 ins. in diameter. The two halves are braced together about 3 ft. apart. As the drag is pulled forward at an angle to the road, the earth along the outer edge runs along the log towards the centre, thus preserving the camber while the surface is made smooth. Dragging is most effective after a shower, when the surface is moist.

4. SURFACING

Earth roads will serve our purpose in the quieter village areas, but where there is likely to be a great deal of

traffic, particularly motor traffic, we must have hard wearing, better roads with water-bound macadam surfaces. This type of road consists of a layer or layers of road materials pressed down on an embankment or on the natural earth itself (called the "sub-grade") to form a strong carriageway for traffic.

On the top there is a "wearing coat" of stone metal, which directly receives the strain of traffic and passes it on to the lower layers. The wearing coat also gives a smooth riding surface and protects the other layers from wear through

SECTION OF A MACADAMISED ROAD

direct contact with traffic as well as from rain-water. Below this is a "base course", also known as "soling" or "bottoming". Right underneath is, of course, the sub-grade. If, however, the sub-grade is not strong enough to take the strain which has been passed on to it through the wearing coat and the base course, another layer is placed between it and the base course, and this is known as the "sub-base".

Let us examine these various layers in greater detail. The wearing coat of stone metal, it is easy to see, must be strong as it is the most exposed. It must be hard enough to resist wear caused by constant traffic, so that maintenance work and repairs are kept to a minimum. It must also be stable enough to pass on strains and stresses to the lower layers without giving way in places itself, and at the same time it must be able to adjust itself if the base on which it rests sinks, up to half an inch if necessary. Nor must we forget the need to keep down costs. The coat should, as far as possible, be made from material which is found close by.

The next layer, the base course, need not be as strong. It can be composed of softer material like *kankar* or sandstone packed to a depth of 6 to 9 ins. Bricks and *moorum* are equally useful.

A sub-base is necessary if the sub-grade soil has poor supporting power when it is wet. Clay and silt are examples of this type of soil. The sub-base generally consists of granular materials like sand, gravel or quarry waste. In the case of fine-grained soils, a sub-base helps drainage and lessens the harmful effect of shrinkage.

If there is no embankment, the sub-grade is the natural soil itself. Where this soil is granular, there is no need for a sub-base layer. Indeed, in some cases, for example firm shale and laterite gravel, the sub-grade may even serve as a base course for the water-bound macadam coat. On the other hand, where there are fine-grained soft soils, both a base course and sub-base are required.

All this adds up to the fact that a good road must have a good foundation. If the foundation is weak, the strain on it must be partly borne by additional layers inserted between the soil and the surface. Is there anything we can do to strengthen the sub-grade? Certainly there is. We can remove soft pockets of soil and replace them by hard, granular material. We can keep water out by providing sub-soil drainage where necessary, for it must be remembered that water weakens the soil. Finally, we can compact the soil by means of a roller or by hand rammers.

Weak soils, i.e. those with a supporting power of less than half a ton per sq. ft., should be avoided as far as possible in building macadam roads. Such soils include soft, wet or muddy clay and alluvial deposits in a damp state. Others slightly stronger, like the black cotton soil, need very thick bases and sub-bases. At the other end of the scale are soils such as compact gravel and firm shale which, as we have already noted, form such excellent sub-grades that in their cases even the base course is sometimes unnecessary in building a road.

We can define a macadamised road surface as one in

which small, angular stones are locked together by rolling. The bonding is done by stone screenings which work their way into the gaps and are set with water. Under the roller the stones adjust their positions so that they support one another. If, before the bonding is complete, any cementing material such as *moorum* or metal dust is added, the stones cannot adjust themselves properly. Each is separated from the others by the new material and is, therefore, deprived of their support. When this happens, the road top does not become a "macadam crust" but a "mud-pie crust". The disadvantage of the latter is that there is no interlocking or adjustment of the stones, and once the cementing material gives way in very dry or very wet weather, the stones are loosened and the road surface is ruined. This does not mean that we should not use a cementing material. Added at the proper time, which is after the interlocking process is complete, it helps to fill in the gaps and strengthens the surface.

Preparation: Let us now see how the road surface is actually prepared. We will presume that everything is in order—the sub-grade, the sub-base (where necessary) and the base course. The base course is usually made a foot wider than the wearing coat in order to provide support for the latter from the sides. The metal is spread evenly over the surface to the thickness wanted, making allowance for the fact that it will shrink under the weight of the roller. After this, the loose metal is hand-packed by trained labourers, the bigger stones being settled first and the smaller ones in the gaps. Our next step is to give a camber to ensure good drainage.

The surface has now to be rolled. When the road metal is comparatively soft, a light roller may be used at the start, but if it consists of hard material like basalt, a heavier roller will be required. The roller should start operating from one side, gradually moving towards the centre. When the metal is well settled, the roller is shifted to the other side. After this preliminary rolling is over, the camber as well as the profile of the road has to be checked. The

rolling is then repeated, this time with a heavy machine. A little water can be used at this stage to help the stones bed down properly. When the interlocking seems to have been completed, a loaded bullock-cart is made to pass over the road. If the surface is as it should be, the cart's wheels will leave no traces. Another test is to place a one-inch thick piece of hard stone in the path of the roller. If the stone is driven into the road, the surface is not satisfactory; if, however, the stone is crushed, it means that the road has been well prepared.

To finish the process, we have now to spread a thin layer of small pieces of limestone or *kankar* over the surface and repeat the rolling. After the *kankar* has been well embedded, the road is heavily watered and once more the roller is brought into use. A final coat is then given, consisting of granular *moorum* or a clay soil mixed with coarse sand to a depth of about $\frac{1}{4}$ in., and the watering and rolling is continued until a paste of this material begins to flow ahead of the roller. Next day the surface is again lightly rolled and covered with a $\frac{1}{4}$ in. layer of sand. Light watering should continue for a week thereafter.

When the road has set properly and is dry it is ready for traffic. In order to distribute the weight of traffic over the full width, it is a good plan to place obstacles in any tracks that may be forming. This is very necessary in our rural areas, where bullock-carts form the chief mode of travel. Bullocks have a tendency to keep to the tracks made by previous carts, thus forming ruts.

While paying such strict attention to the metalled surface, we must not forget the "berms" i.e. the portions of the formation on either side of the metalled part. Traffic will also pass over the berms, so they should be made of well packed earth, strengthened with *moorum,* if it is available.

Like earth roads, water-bound macadam roads need constant attention. Ruts and pot-holes must be repaired as soon as they appear for, as everyone knows, a little work done today will save a lot tomorrow. A useful protection for the road is to spread a thin layer of *moorum* or stone

screenings over the surface after very heavy rain and occasionally during dry weather. This is called "blinding." Another thing to remember is that the top layer of the road wears thin after some years, the time taken depending on the traffic. When this happens, a new coat 2 to 3 ins. thick should be provided.

Sometimes, after heavy use, a road surface becomes corrugated or wavy. These corrugations are due to defects in building. Among the causes are weakness in the sub-grade (many roads in sandy areas become corrugated), failure of the various layers to hold together, insufficient attention to interlocking the road metal and using too heavy a roller, which crushes the metal. Other causes are jerky rolling and opening the road to traffic before the macadam has fully set. It is clear that all these faults can be prevented. If proper care is taken in building the road, corrugations will not occur.

Bitumen Surfaces: As far as the rural areas are concerned, we are not likely to go beyond the water-bound macadam stage for years to come. However, since we are on the subject, we may as well say something about the higher, dust-proof types of road surfacing.

The materials used for obtaining these surfaces are bitumen, tar and cement concrete. Cement concrete roads are still rare in India, but the other two types are in common use in the cities and towns and for important roads like the national highways. In surfacing with bitumen or tar, our first step is to ensure that the water-bound macadam is clean and free from ruts and pot-holes. Wire brushes should be used to clean the surface, which is then dusted with gunny bags.

Meanwhile, hard stone chips of about ½ in. size are collected in heaps at the side of the road. The bitumen (or tar) is heated in special boilers to a high temperature, and is then applied to the surface by means of a pressure sprayer or pouring cans. The spraying is done in lines parallel to the road. The stone chips are then spread uniformly over the binder. The surface is rolled till the

stones are well embedded, and the road can be opened to traffic soon after.

5. HILL ROADS

We have discussed in general terms the methods we use and the problems we meet in building roads. There are, however, certain special difficulties to be overcome in building roads through hilly country. We shall now consider these difficulties.

The first problem is the alignment. What must we bear in mind in deciding what route a road should take in linking one village with another that lies some miles away, across hills and valleys? There are two things. The first is the gradient : the road must not be too steep. It should not rise to the top of a hill or go right down to the floor of a valley unless this is absolutely necessary. A steady, gradual upward or downward slope—according to whether the second village is higher or lower than the first—is what we want. A gradual slope will, however, add to the normal length of the road. This cannot be helped, but obviously we are not going to allow the road to be longer than is necessary, as this will increase our expenditure. A limit must be set.

This brings us to our second point : how do we work out this limit? We do it this way. Suppose one of the villages is 1,320 ft. higher than the other. The road is going to slope upwards gradually, at an average gradient of 1 in 20, let us say. This means that for every foot of the climb we shall be building 20 ft. of road. As we have to climb 1,320 ft., the road will be 1,320×20 ft. which is 26,400 ft. or exactly 5 miles long. We must remember, however, that this calculation takes no account of the various factors which go towards deciding the alignment. It is no more than an indication of the shortest possible length of road between

the two villages. We have only to see that our chosen alignment is not very much longer than the calculated length—5 miles in this case.

Another problem is that of limiting the quantity of earthwork needed for a road. Where the hill slope is not very steep, we cut into the hill for two-thirds of the required width of the road, and use the displaced earth to form the remaining portion on the valley side. Where the hill slope is steep, it is desirable to obtain the full road width by cutting into the hillside. The only objection to this is that the road will hug the hillside, winding in and out with the gulleys and rain-water channels so as to make a traveller quite giddy. To overcome this winding to some extent, we can carry the road across the smaller gulleys, building stone walls on the valley side to retain the road and culverts to carry off rain-water, which would otherwise weaken the soil.

Drainage is one of the most important things in road construction, for there is nothing that can damage a road more than rain-water. For a hill road, it is necessary to have a catch-water drain higher up the slope. It is a good

plan to use the earth displaced in digging the drain to form a bund along the lower edge as an additional safety measure. Culverts are generally situated at points where natural gullies meet the road. It is best to have one every furlong or so, especially in areas where the rainfall is heavy.

A fourth problem of hill roads is the prevention of landslides. We need not go into the causes of such mishaps except to say that water is largely responsible. So we try to keep the soil as dry as possible by making a series of *kutcha* drains filled with gravel or coarse sand. Tree planting also helps, for the roots bind the soil, keeping it firmly together. In some cases, stone walls may be built to support the hillside. These walls are costly, however, and they should not be undertaken unless they are really necessary.

We have seen that as much as one-third of a hill road may be built of earth while the remaining portion is part of the hill itself. On roads of this type there sometimes occurs what is known as "road slip." The first sign of a road slip is a crack at the point where the hill portion ends and the earth portion begins. If the crack is allowed to widen, water may enter and cause the earth portion to collapse. If good care is taken during the actual building of the road, a slip is not likely to occur, but it is wise to keep a sharp look-out for cracks, especially during the rainy season.

There is one more point that may be mentioned. To motorists, some hill roads, with their blind corners and hairpin bends, are a nightmare. Little can be done about the bends, for the road must follow the outline of the hill. We can, however, make things more comfortable by trying to give as much view of the way ahead as possible. One method of doing this is by clearing some of the overgrown vegetation round bends and cutting branches of trees that obscure the view. Wherever possible, the hillside also should be cut to improve visibility.

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